Coastal Engineering Technical Note

IRREGULAR WAVE DIFFRACTION BY GODA'S METHOD

PURPOSE: To provide a simplified method for determining random wave diffraction coefficients for a semi-infinite breakwater.

GENERAL: Studies of wave diffraction have typically assumed that waves are monochromatic. Actual sea waves occur in a directional spectrum of many wavelengths or periods. Wave diffraction methods which are based on monochromatic waves, and which ignore the wave spectrum, may give an incorrect prediction (overestimation) of wave heights near a coastal structure.

Goda, et al. (1978) and Goda (1985) discuss a means of determining wave diffraction coefficients at a large island or semi-infinite length breakwater for directional wave spectra. This method is based on a dimensionless frequency parameter, S_{max}. Recommended values of this parameter for different types of waves in deep water, $(S_{max})_o$, are:

TYPE OF WAVE	$(S_{max})_o$
Wind Waves	10
Short Swell (large wave steepness)	25
Long Swell (small wave steepness)	75

Kraus (1984) has developed simple approximations based on the work of Goda which result in a relatively easy procedure for calculating the diffraction coefficients. These approximations provide wave heights along a coast, e.g., for longshore transport calculations, with little loss of accuracy. However, in some areas of the shadow zone between the breakwater and the shoreline, particularly close to the breakwater, the approximations may underestimate the diffraction coefficient, i.e., not provide a conservative estimate.

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METHOD: Goda defines the parameter, S_{max}, in shallow water in terms of the deepwater parameters, $(S_{max})_o$, by using Figure 1, in which d is the water depth at the breakwater tip, L_o is the deepwater wavelength of the significant wave, and α_o is the angle of the wave crest with respect to the bottom contours where the wave enters shallow water ($\alpha_o = 0^o$ if the wave crest is parallel to the bottom contours).

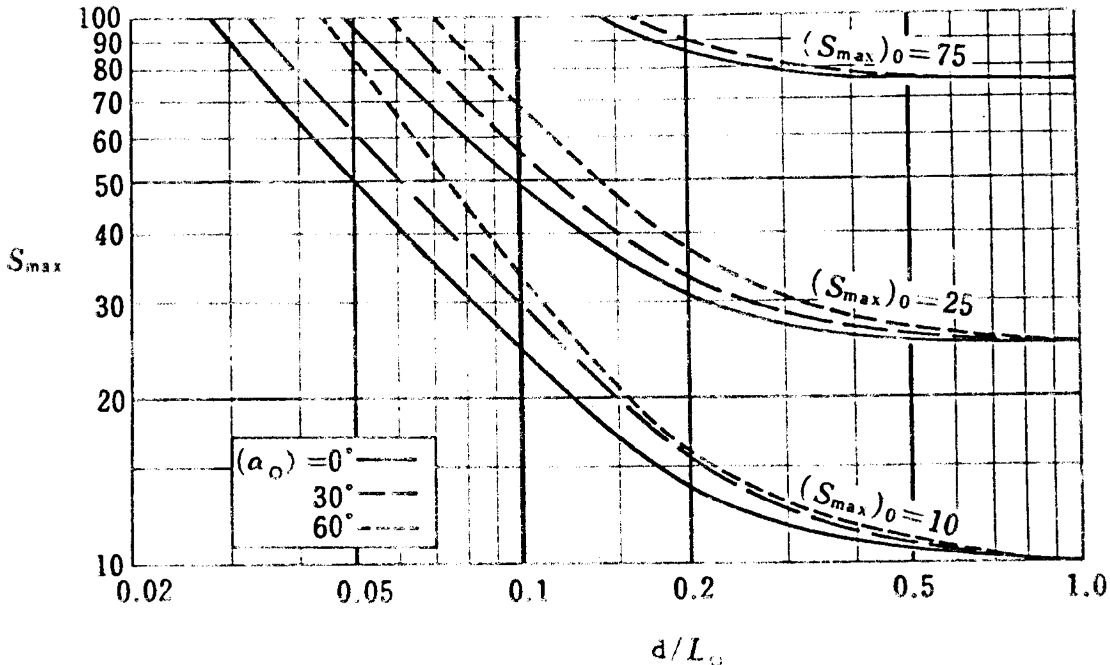


Figure 1. Change of maximum directional concentration parameter, S_{max}, due to wave refraction in shallow water (Goda, 1985)

After the value of S_{max} is determined, the value of $K(\Theta)$, the diffraction coefficient along a line at an angle Θ from the wave direction at the breakwater tip (see Figure 2), is determined as a decimal fraction of the wave height at the tip. Kraus (1984) gives this as an approximation by the equation

$$K\Theta = \sqrt{0.5\left[\tanh \frac{S_{max}\,\Theta}{W} + 1\right]}$$

where Θ is in radians, and W is given by

$$W = -0.000103\ S_{max}^2 + 0.270\ S_{max} + 5.31.$$

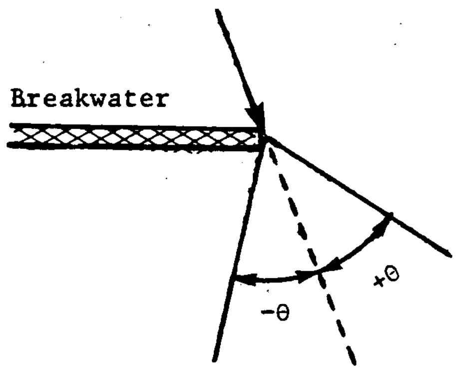
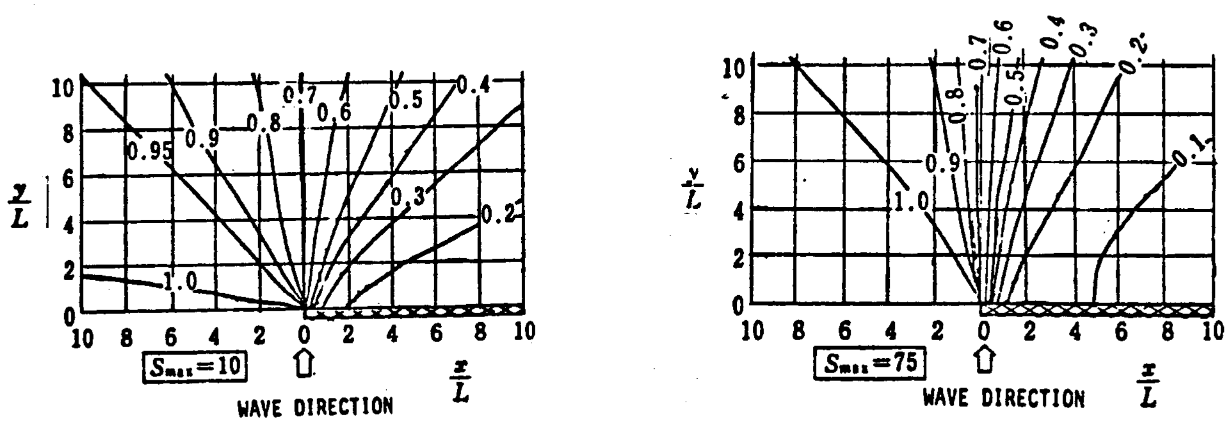


Figure 2. Definition sketch for using the random wave diffraction method of Goda (1985)

The diffraction coefficients obtained by Kraus compare favorably with those computed more exactly by Goda, et al. (1978), except where Kθ <0.2. Where K(θ) <0.2, the approximations of Kraus will underestimate the value of Kθ. However, this error is not expected to have significant impact since it is in a small waveheight region.

Examples of the more exact value of K(θ) obtained by Goda are shown in Figure 3.



(a) S_{max} = 10 — HEIGHT RATIO, K(θ) (b) S_{max} = 75

Fig. 3 Diffraction Diagrams of a Semi-Infinite Breakwater for Directional Random Waves of Normal Incidence (Goda, et al., 1978)

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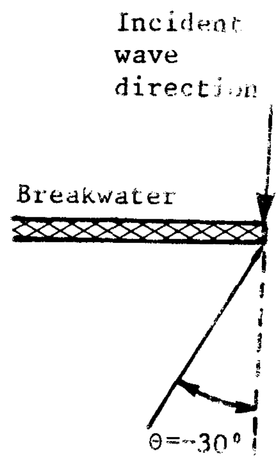
GIVEN: Wind waves are determined to have a significant period, T, of 12 seconds and a deepwater wavelength, L_o of 738 feet. The wave angle, α_o, with respect to the bottom contours where the wave enters shallow water is 30°. A breakwater tip is in a water depth of 30 feet. The wave direction at the breakwater tip is at the angle of 90° shown.

FIND: The diffraction coefficient K along the line at an angle of -30° shown.



SOLUTION: At the breakwater tip

$$\frac{d}{L_o} = \frac{30}{738} = 0.0407$$

$(S_{max})_o = 10$ (for wind waves)

From Figure 1, for $(S_{max})_o = 10$,

$\frac{d}{L_o} = 0.0407$ and $\alpha_o = 30°$, $S_{max} = 75$

$$W = -0.000130\, S_{max}^2 + 0.270\, S_{max} + 5.31$$

$$W = -0.000130\,(75)^2 + 0.270\,(75) + 5.31 = 24.83$$

$$\theta = -30 = -0.5236 \text{ radians}$$

$$K(\theta) = \sqrt{0.5\left[\tanh\left(\frac{S_{max}\theta}{W}\right) + 1\right]} = \sqrt{0.5\left[\tanh\left(\frac{75\ (-0.5236)}{24.83}\right) + 1\right]}$$

$$K(\theta) = 0.201$$

This is comparable to the value obtained from Figure 3b.

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REFERENCES:

Goda, Y. 1985. Random Seas and Design of Maritime Structures, University of Tokyo Press, Tokyo, Japan.

Goda, Y., Takayama, T., and Suzuki, Y. 1978. "Diffraction Diagrams for Directional Random Waves," Proceedings of the Sixteenth International Conference on Coastal Engineering, ASCE, Chapter 35, pp. 628-650.

Kraus, N. C. 1984. "Estimate of Breaking Wave Height Behind Structures," Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE, Vol. 110, No. 2, pp. 276-282.